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AIR QUALITY

THUNDER BAY

Annual Report, 1976.



Ontario

Ministry
of the
Environment



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AIR QUALITY

THUNDER BAY

Annual Report, 1976

ONTARIO MINISTRY OF THE ENVIRONMENT

June, 1977

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SUMMARY

This report presents results of the 1976 air monitoring programme conducted in Thunder Bay by Ontario Ministry of the Environment. Measurements were made of dustfall, suspended particulate, sulphation rate, hydrogen sulphide, and sulphur dioxide. Special surveys were also carried out near specific local industries.

Average dustfall was above the Ontario criterion at four of 14 sites, but the average for the city was about 14 percent lower in 1976 than in 1975. Grain dust was an important component of dustfall at monitoring sites near grain elevators. Levels of sulphates in dustfall were generally low. Concentrations of suspended particulate showed little change from 1975 for the city as a whole. Suspended particulate was above the provincial criterion at three stations and within the criterion at three others. Concentrations of heavy metals, sulphate, and nitrate in suspended particulate were low. Highest levels of dustfall and suspended particulate occurred in spring and summer months and were associated with easterly winds. Dust levels monitored in Thunder Bay were slightly higher than Sudbury, slightly lower than Sault Ste. Marie and much lower than those in a major industrial city like Hamilton.

Soiling index, a measure of the darkening properties of particulate matter, was within the Ontario criterion at the one Thunder Bay monitoring station.

Very low concentrations of hydrogen sulphide were recorded at 435 James Street South. When the monitor was moved to Montreal Street, the levels found were substantially higher but still within acceptable limits.

Sulphation rates, monitoring the presence of sulphur-containing pollutant gases, were low at all 10 Thunder Bay sites in 1976. Sulphur dioxide concentrations also met all criteria at the Ministry's two stations, but the hourly criterion was exceeded 17 times, and the daily criterion twice, at two of five monitoring stations maintained by Ontario Hydro. Most of the high levels recorded by Ontario Hydro were attributed to sulphur dioxide emissions from Great Lakes Paper Limited.

INTRODUCTION

The Ontario Ministry of the Environment, and its predecessor agencies, have conducted an air quality monitoring programme in Thunder Bay since 1963. An historical review of this activity was presented in a report issued in 1976 (1), which summarized air quality data for the period 1963 to 1975. The 1976 survey programme continued with little change from 1976. One new instrument was added, a soiling index monitor at 435 James Street South, and the hydrogen sulphide analyzer was moved from 435 James Street to Montreal Street.

The 1976 monitoring network included 14 dustfall jars, 6 high-volume particulate samplers, 1 soiling index monitor, 1 hydrogen sulphide analyzer, 10 sulphation candles or plates and 2 sulphur dioxide analyzers. An additional 5 sulphur dioxide monitors were operated by Ontario Hydro.

Special air quality assessment surveys were also conducted during the year near specific Thunder Bay industries. Investigations of this type included vegetation injury evaluation, snow sampling, and/or air monitoring in the vicinity of the three Abitibi paper mills, near the Great Lakes Paper complex, and in the area surrounding the site of the Thunder Bay Terminals project. This report contains only a brief summary of these special investigations, each of which is fully described in separate reports.

PARTICULATE POLLUTANTS

(a) Dustfall

Dustfall, one of the most visible classes of air pollutants, comprises particulate matter which settles out from the atmosphere under the influence of gravity. It is measured by exposing open-top vessels for 30 days and weighing the collected matter. Results are expressed in tons per square mile per month. The soluble and insoluble fractions of dustfall may also be analysed for specific constituents: Thunder Bay dustfall was analysed for sulphate content and the insoluble fraction was examined for the presence of grain dust, wood char, fly-ash, iron oxide, silica, and other matter.

Dustfall recorded in 1976 is summarized in Table 1 for 14 sites whose locations are shown in Figure 1. Monthly dustfall exceeded the Ontario criterion at least once during the year at eight stations, but averages above the annual criterion occurred at only four locations. The two highest averages were encountered at stations 63021 and 63026, the former near a bulk storage operation (Valley Camp Limited) and the latter close to grain elevators.

Soluble sulphate in dustfall (Table 2) was generally very low and accounted for about only 5 percent of total dustfall. An exception was the level of sulphate at station 63021 (Mission Island), which was two to three times the average at other locations and comprised just over 10 percent of total dustfall for that site. Increased sulphate at the Mission Island station was attributed to airborne particulate matter blown from piles of stored material at Valley Camp.

Results of microscopic examination of the insoluble portion of dustfall at four Thunder Bay locations is presented in Table 3. Grain dust was an important constituent of dustfall at stations 63024 and 63026, both near grain elevators. Non-industrial contaminants (soil, plant and insect debris, etc.) were dominant at stations 63005 and 63040, both located some distance from significant industrial air pollution sources. Fly-ash and iron oxide each rarely exceeded 1 percent of insoluble dustfall, and wood char accounted for about 10 percent. Since the values for all these components of dustfall were given as volume percent, it was not possible to compare their relative weight contribution to total dustfall.

Comparison between average dustfall for the years 1973 to 1976 (Table 4) shows a trend toward decreasing dustfall levels. The 1976 average of 12 tons per square mile represented a decline of about 14 percent from 1975 and nearly 30 percent from 1973. This situation is illustrated in Figures 2 to 5, where the area affected by above-criterion dustfall levels significantly decreased during the 1973-76 period. Further improvement may be anticipated with continued progress in dust control programmes at local grain elevators.

Average dustfall was 8 tons per square mile in winter (January-March), 20 tons in spring (April-June), 16 in summer (July-September), and 10 in autumn (October-December). The same trend was noted in 1975. The higher spring and summer averages coincide with maximum grain handling and shipping activity and with re-entrainment of ground-level dust blown about by the wind. During late autumn and winter, sources of ground-level dust (parking areas, dirt-covered roads, etc.) are frozen over and grain movement operations are at a minimum for the year.

Dustfall levels averaged 17 tons per square mile with easterly prevailing winds and 10 tons with west winds. Comparable figures for 1975 were 17 and 13 tons, respectively. Since, with easterly winds, most monitoring locations are downwind of grain elevators, these data provide supporting evidence that grain elevators contribute significantly to dustfall loading in Thunder Bay.

(b) Suspended Particulate

(i) High-volume method

Suspended particulate constitutes particulate matter of small size which remains in the atmosphere for extended periods. In the high-volume sampling method, a measured volume of air is drawn through pre-weighed glass fibre filters for 24-hour periods every sixth day. The filters are re-weighed after exposure to determine the quantity of matter collected. Results are expressed in micrograms per cubic metre of air ($\mu\text{g}/\text{m}^3$). Exposed filters may also be chemically analysed for specific contaminants. Filters from two of the six Thunder Bay monitoring sites were submitted for determination of nitrate, sulphate, and a range of heavy metals.

Complete results for total suspended particulate are given in Table 5. The 24-hour criterion ($120 \mu\text{g}/\text{m}^3$) was frequently exceeded at stations 63017, 63022, and 63040 and occasionally at the other three sites. As in 1975, concentrations were highest at station 63017 and lowest at station 63018. The annual criterion ($60 \mu\text{g}/\text{m}^3$) was exceeded

at three of six sites. Unexpectedly high values were recorded at station 63040, particularly in September. Evaluation of meteorological data indicates that strong westerly winds occurred on September sampling dates and may have caused dust from piles of material stored in an adjacent Ministry of Transportation and Communications yard to be blown toward the sampling unit.

Concentrations of heavy metals, sulphate, and nitrate in suspended particulate at two stations are summarized in Table 6, which also includes comparable data for 1971. Levels of cadmium, chromium, copper, manganese, nickel, vanadium, and zinc were very low in both 1971 and 1976. Lead concentrations were significantly lower in 1976 than 1971, presumably because of pollution control devices fitted to new vehicles in recent years. Iron levels were higher than those of other heavy metals, but were not considered excessive. Average nitrate and sulphate concentrations had not changed appreciably from 1971 to 1976 and were lower than averages reported from urban centres in southern Ontario (2).

Average total suspended particulate in Thunder Bay declined from 1973 to 1975 but remained essentially unchanged from 1975 to 1976 (Table 7). In 1976, average concentrations were $33 \mu\text{g}/\text{m}^3$ in winter, 79 in spring, 103 in summer, and 61 in autumn, thus confirming the trend found for dustfall. On sampling dates with easterly prevailing wind, particulate concentrations averaged $91 \mu\text{g}/\text{m}^3$. Values for southerly, westerly and northerly winds were 70, 78 and 46, respectively. The average of $78 \mu\text{g}/\text{m}^3$ associated with west wind was higher than anticipated and may have reflected the influence of a localized contamination problem (discussed earlier) at station 63040, or the presence of elevated particulate from forest fires west of Thunder Bay.

(ii) Coefficient of haze method

Soiling index is an indication of the soiling or darkening properties of suspended particulate matter. A measured volume of air is continuously drawn through a circular area on a paper filter tape producing a stain or spot from the deposited particulate matter. Samples

are taken automatically for one or two-hour intervals. The reduction of light through the sampling spot is measured as coefficient of haze (COH) units. The soiling index, an expression of the opacity and darkness of the deposit, is given as the number of COH units per 1000 linear feet of air drawn through the filter. This method of suspended particulate monitoring has the distinct advantage of continuous automatic sampling over long periods of time.

Measurement of soiling index began in Thunder Bay in February, 1976, at station 63040. Results for the year are summarized in Table 8, which shows that there were no violations of the 24-hour criterion (1.0 COH's/1000 ft). The 1976 mean of 0.17 COH's/1000 ft. was also well below the annual criterion of 0.50 COH's.

GASEOUS POLLUTANTS

(a) Hydrogen Sulphide

Hydrogen sulphide (H_2S) is an atmospheric contaminant commonly associated with kraft pulp mills. H_2S , and other organic sulphide compounds usually found with it, are unpleasant smelling gases at very low concentrations. At higher levels, hydrogen sulphide may blacken lead-based paints, injure vegetation, or cause respiratory irritation in nearby human populations.

Hydrogen sulphide has been monitored since June, 1975, at station 63040, which is about 3000 m (metres) north-northeast of the Great Lakes Paper kraft mill. H_2S measurement continued until the end of October, 1976, when the instrument was moved to a Montreal Street site about 925 m northeast of the mill. The analyzer used at both locations was a Philips model PW9700. This instrument operates on the principle of continuous coulometric titration and is sensitive to mercaptan compounds as well as hydrogen sulphide. Data for station 63040, of limited quantity because of instrument malfunction, are summarized in Table 9 and values for station 63046 (Montreal Street) are shown in Table 10. Concentrations at station 63040 were very low and never approached the Ontario criterion of 20 ppb (parts per billion) for a

1-hour average. Much higher levels, although still below the criterion, were recorded at the Montreal Street station. At this site, all measurable H_2S values were associated with west-southwest to south-southwest winds, thereby implicating the Great Lakes mill as the emission source.

(b) Sulphation Rate

Sulphation rate is measured by exposing small plastic plates or candles coated with lead dioxide to the atmosphere for 30-day periods. Lead dioxide reacts with gaseous sulphur compounds in the atmosphere to form lead sulphate. The quantity of sulphate formed is analytically determined and results reported as milligrams of sulphur trioxide per hundred square centimetres per day ($\text{mg SO}_3/100 \text{ cm}^2/\text{day}$). The lead candle or plate method is normally used for the detection of sulphur dioxide. However, because of its oxidizing power, lead dioxide also converts other reactive sulphur compounds to sulphate. In an area containing more than one reactive gas, the lead dioxide candle or plate method will therefore yield results representing the combined effect of the presence of all reactive compounds. In most parts of Thunder Bay, sulphur dioxide is considered to be the primary reactive agent.

Sulphation rates for 10 Thunder Bay stations are presented in Table 11. All values were below the current provincial criterion of $0.70 \text{ mg SO}_3/100 \text{ cm}^2/\text{day}$. The highest average was recorded for station 63019 (Main Street Sewage Treatment Plant), followed by station 63004 (24 Mountain Road). The former site may have been influenced by emissions of sulphide compounds from the sewage plant and the latter by sulphur dioxide emissions from Abitibi's Mission Mill. Table 12 shows that sulphation rates were uniformly low during the 1973 to 1976 period. Average sulphation rates were nearly the same, 0.10 and 0.09 mg, for easterly and westerly monthly prevailing winds respectively. By season, the rates averaged 0.11 in winter, 0.10 in spring, 0.08 in summer, and 0.09 in autumn. The slightly higher values for autumn and winter were attributed to the use by local industry of fuels with higher sulphur content (coal and oil as opposed to gas) during cold months of the year.

(c) Sulphur Dioxide

Fuel combustion and industrial emissions are significant sources of sulphur dioxide (SO_2), one of the world's major atmospheric pollutants. The adverse effects of SO_2 have been well documented with respect to human health, vegetation, and corrosion of building materials. In Thunder Bay, industrial sources of SO_2 emissions include four sulphite pulp mills, a thermal generating station on Mission Island, and fuel combustion by several local industries. Total SO_2 emissions are not large, however, and the sum of all daily SO_2 discharges in Thunder Bay has been estimated at less than 100 tons.

Ministry of the Environment continuous sulphur dioxide analyzers are sited in two locations in Thunder Bay. The monitor used in 1976 at Dawson Court (station 63012) was a Davis model 7010 RPL. This instrument operates on the principle of conductivity which, unfortunately, results in interference from contaminants other than sulphur dioxide (e.g., carbon dioxide) which affect the conductivity of the absorbing solution. Carbon dioxide interference, together with instrument malfunctions, resulted in considerable loss of data, particularly toward the end of the year. A summary of hourly averages for the station (Table 13) indicates that the hourly criterion of 0.25 ppm (parts per million) was met at all times. The maximum daily average of 0.03 ppm was well below the 24-hour criterion of 0.10 ppm, and the annual average of 0.009 ppm was much lower than the permitted maximum of 0.020 ppm.

The analyzer used at 435 James Street (station 63040) was a Philips model PW9700. This instrument operates on the principle of continuous coulometric titration and is not sensitive to potential interference from other pollutants. Data for this location are summarized in Table 14. The maximum averages of 0.13 ppm (hourly), 0.02 (daily), and 0.001 (annual) were all well below Ontario criteria.

Philips model PW9700 sulphur dioxide analyzers were also employed in Ontario Hydro's monitoring network (stations 63023, 63041 - 63044). The frequency distribution of hourly values for all five stations is given in Table 15. Lowest SO_2 concentrations occurred at

station 63043, the site most remote from any industrial source. Hourly and daily SO₂ averages here, and at stations 63023 (Walsh Street) and 63042 (South Sewage Treatment Plant), were all below the allowable maxima of 0.25 ppm and 0.10 ppm, respectively. The hourly criterion was exceeded 15 times at station 63044 (James Street South and Highway 61B) and twice at station 63041 (summit of Mt. McKay). The daily criterion was also exceeded twice at 63044, on April 2 and 13. An analysis of all above-criterion hourly values is presented in Table 16. Most of the high values occurred in early April. A maximum of 0.87 ppm, more than three times the criterion, was recorded on April 2 and April 13. Wind directions associated with all fumigations at station 63044 strongly implicated Great Lakes Paper as the source of emissions.

SPECIAL SURVEYS

(a) Abitibi Paper Mills

A snow sampling survey was conducted in January and February in the vicinity of Abitibi's three sulphite pulp mills when all were closed because of a prolonged labour strike. At 30 sampling sites near the three mills, the concentrations of all potential contaminants (calcium, chloride, sodium, and sulphate) were within the range considered normal for snow remote from industrial contamination. These data established background levels for comparison with a subsequent survey scheduled during normal mill operating conditions in early 1977.

A vegetation assessment survey conducted in August revealed no evidence of acute sulphur dioxide injury to plant foliage near any of the sulphite mills.

(b) Great Lakes Paper Mill

Snow sampling surveys in 1974 and 1975 around the Great Lakes Paper complex demonstrated the presence of an area of snow containing elevated concentrations of calcium, sodium, and sulphate. Calcium levels were similar, for comparable distances, to those near most other

kraft mills investigated in the region, but sodium and sulphate concentrations were much lower. A 35-site survey during the strike period in early 1976 showed significant decreases in all contaminants to levels similar to those for snow remote from industry.

No visible symptoms of sulphur dioxide damage were observed on any vegetation near the Great Lakes sulphite mill.

(c) Thunder Bay Terminals Project

Since early 1975, vegetation and soil sampling, snow sampling, and air monitoring programmes have been conducted by Ministry of the Environment and a firm of consultants to obtain pre-operational environmental information in an area where a coal trans-shipment facility is scheduled for start-up in late 1978.

Low levels of aluminum, arsenic, calcium, carbon, chloride, iron, lead, sodium, sulphate and zinc were found in snow at the project site on McKellar Island and at sample points in adjacent parts of the city. Significant arsenic and iron contamination occurred in snow near Valley Camp's bulk storage operation a short distance to the south of McKellar Island, and slightly elevated levels of aluminum and sulphate were found in snow near Valley Camp and near coal piles at Ontario Hydro's Mission Island generating station.

Vegetation and soil sampling in the same area showed that concentrations of aluminum, arsenic and iron were within the range considered normal.

Total dustfall and suspended particulate at three monitoring locations near the project site were just at, or below, the annual criteria and were similar to levels measured at the Ministry of the Environment station at McKellar Hospital. Dustfall was much higher at five sites in the immediate vicinity of Ontario Hydro's coal piles where the highest annual average was nearly three times the criterion.

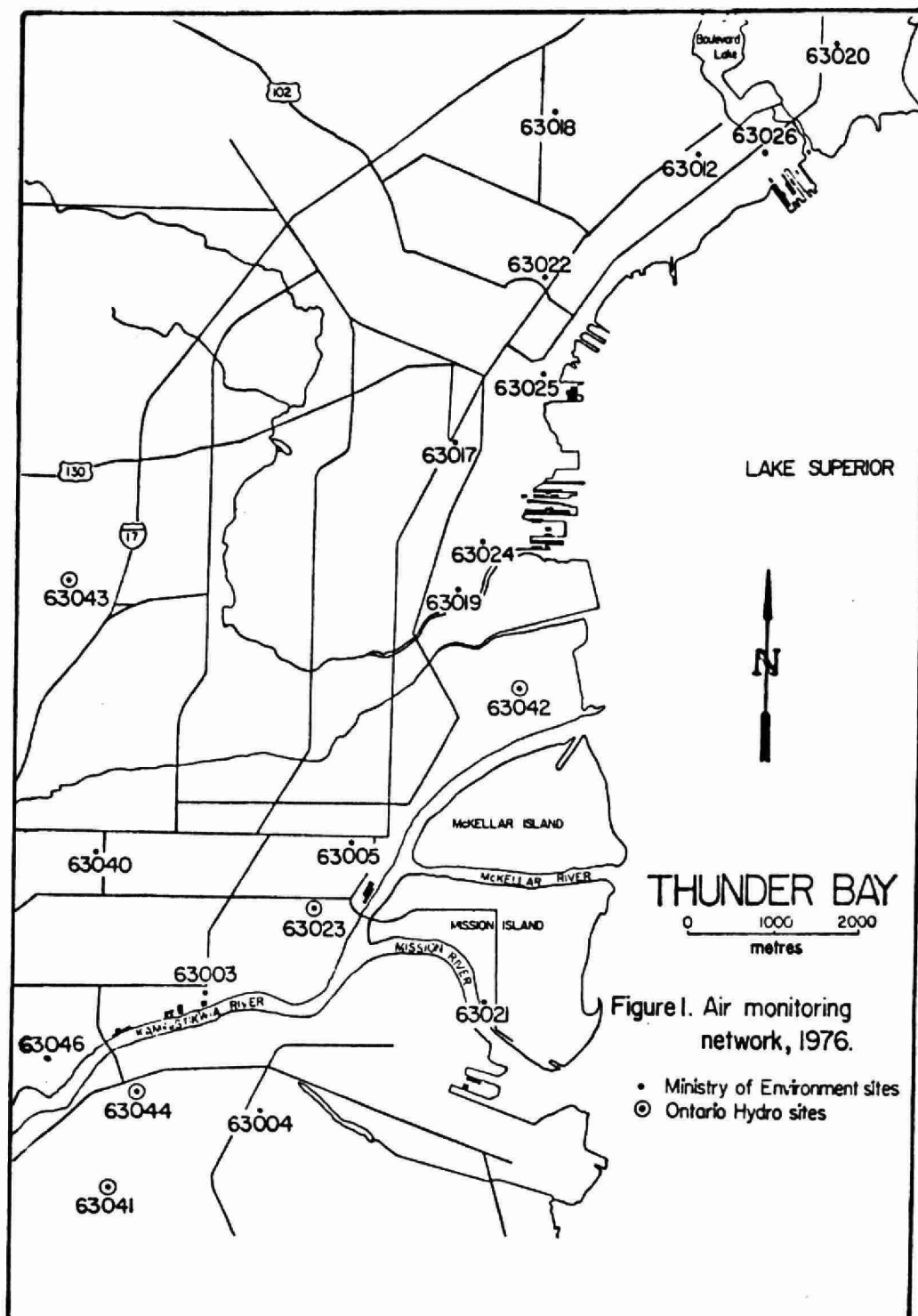
ACKNOWLEDGEMENTS

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- Thunder Bay Laboratory, Northwestern Region, for dustfall and suspended particulate weight determinations, for sulphate analysis of dustfall, and for chemical analysis of snow meltwater.
- Air Quality and Meteorology Section, Air Resources Branch, for processing data from continuous air monitoring instruments and for instrument calibration.
- Air Quality Laboratory Section, Laboratory Services Branch, for preparation and analysis of sulphation candles and plates, and for chemical analysis of suspended particulate.
- Physical Methods Section, Laboratory Services Branch, for microscopic examination of insoluble dustfall.
- Organic and Inorganic Trace Contaminant Sections, Laboratory Services Branch, for chemical analysis of snow meltwater.
- Environmental Protection Service, Environment Canada, for providing sulphur dioxide, soiling index, and high-volume sampling instruments for station 63040.

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2. Foster, A.B. (1977). Personal communication. Laboratory Services Branch, Ontario Ministry of the Environment.



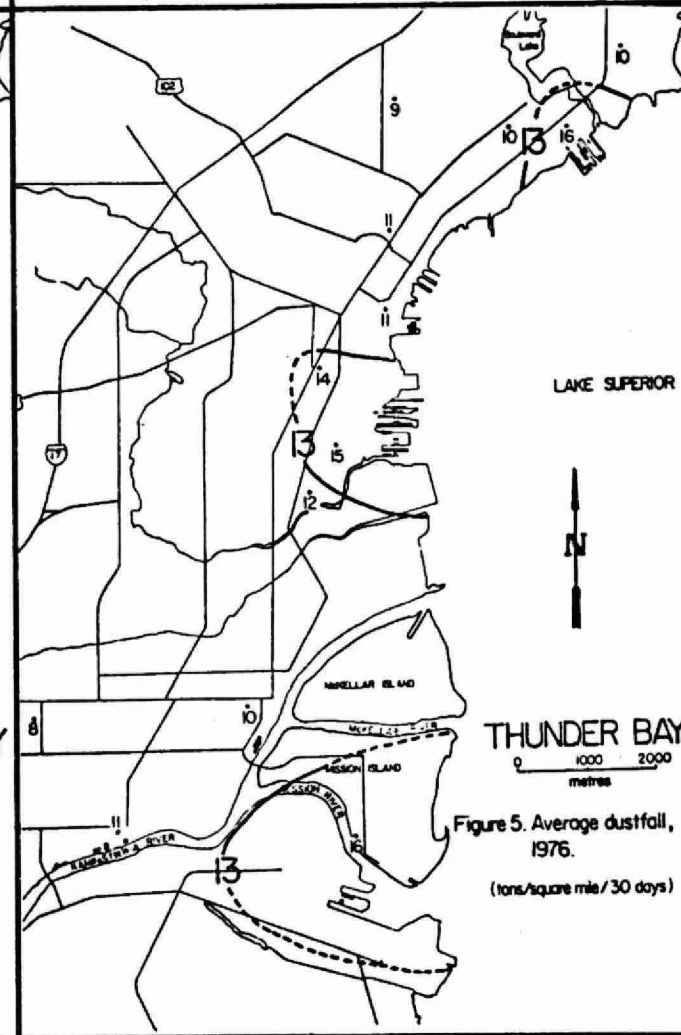
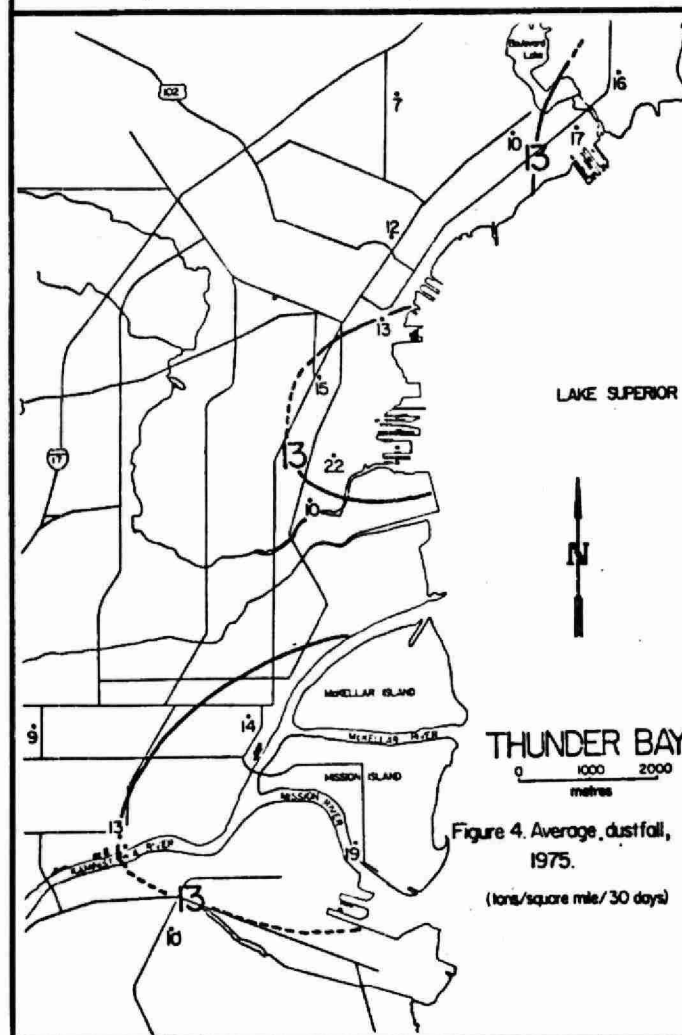
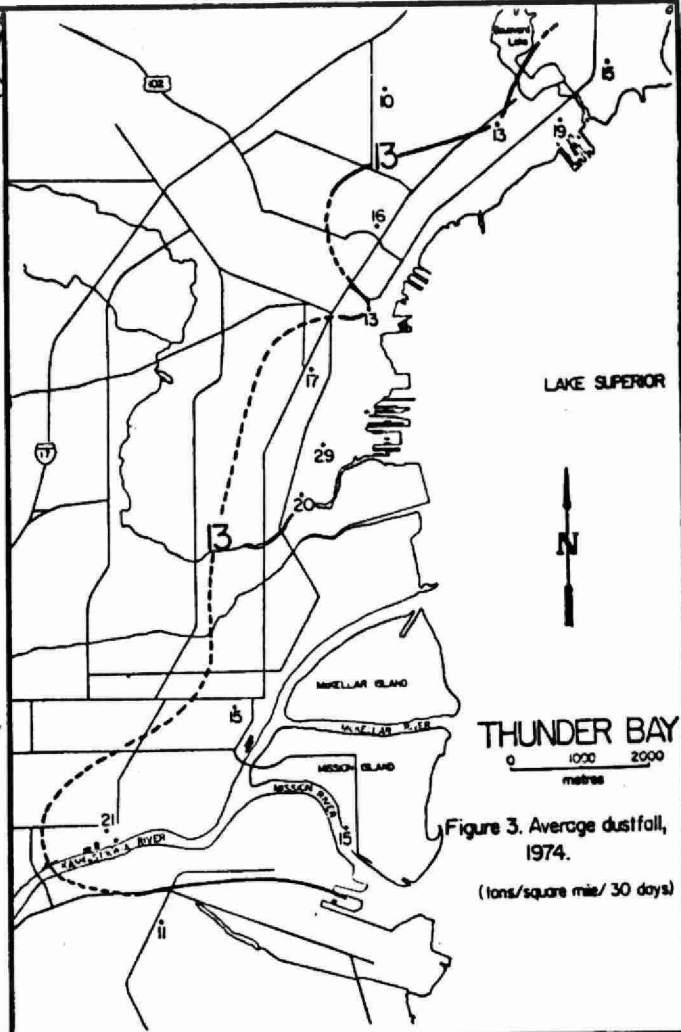
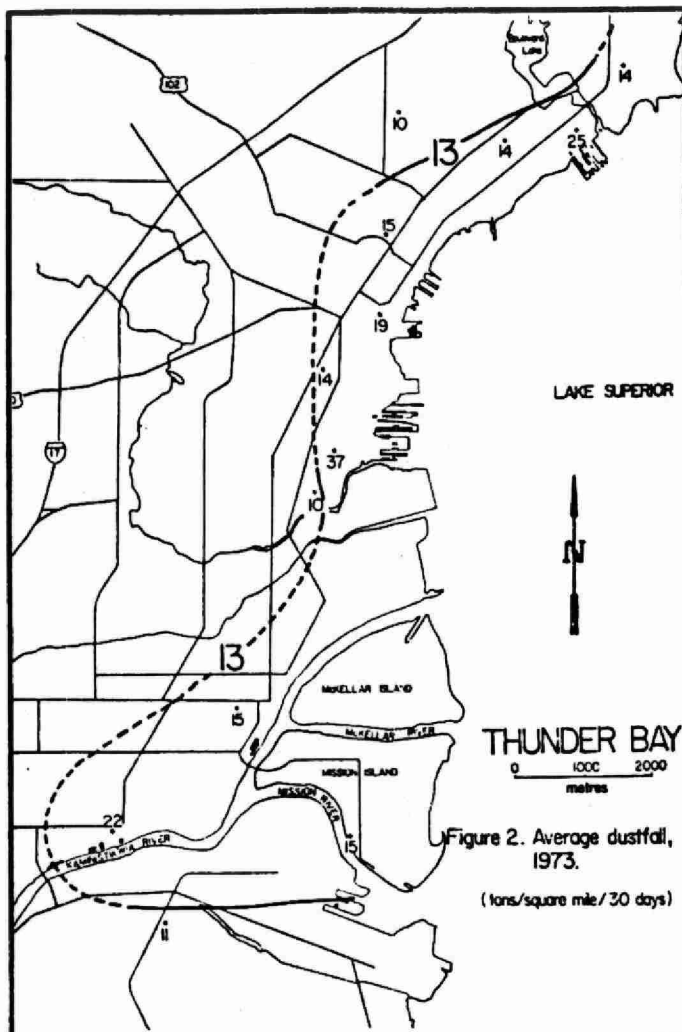


TABLE 1. Dustfall (tons/square mile/30 days), Thunder Bay, 1976.

Station	Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
63003	185 Gore St.	2	8	10	19	<u>24</u>	<u>22</u>	12	17	10	9	6	4	12
63004	24 Mountain Rd.	1	3	7	5	13	10	8	12	9	15	13	6	9
63005	McKellar Hospital	3	8	16	<u>21</u>	15	14	7	10	8	8	5	10	10
63012	Dawson Court	2	6	11	19	14	16	14	10	8	10	4	4	10
63017	521 Memorial Ave.	3	6	12	<u>22</u>	17	18	19	20	16	17	13	5	<u>14</u>
63018	St. Ignatius School	1	5	6	10	11	10	11	19	14	9	4	3	9
63019	Main St. Sewage Plant	3	3	9	11	19	15	<u>22</u>	13	13	17	9	5	12
63020	Hodder Ave. Fire Hall	3	4	8	17	14	8	16	8	9	12	11	4	10
63021	Mission Island	9	8	8	12	12	<u>40</u>	20	13	15	14	19	20	<u>16</u>
63022	14 Algoma St.	5	6	14	<u>24</u>	17	12	13	12	9	10	7	3	11
63024	Hammond Ave./Inter-City	7	11	14	15	18	<u>26</u>	18	20	<u>24</u>	14	8	9	<u>15</u>
63025	Manitou St.	4	3	9	16	19	18	14	16	12	12	9	2	11
63026	North Cumberland Hydro	4	9	13	<u>25</u>	<u>32</u>	<u>25</u>	17	<u>26</u>	14	13	13	4	<u>16</u>
63040	435 James St. South	1	4	8	13	12	15	5	9	6	8	6	3	8

* Values exceeding criteria of 20 (monthly) or 13 (annual average) are underlined.

TABLE 2. Soluble sulphate (tons/square mile/30 days) in dustfall, Thunder Bay, 1976.

Station	Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
63003	185 Gore St.		0.3	0.7	0.8	0.3	0.9	0.9	0.4	0.5	0.4	0.2	0.4	0.5
63004	24 Mountain Rd.		0.2	0.7	1.1	0.3	1.1	0.6	0.6	0.5	0.7	0.5	0.6	0.6
63005	McKellar Hospital			0.7	1.1	0.1	0.9	0.5	0.3	0.5	0.3	0.2	0.6	0.5
63012	Dawson Court		0.2	0.6	1.1	0.2	1.4	0.5	0.3	0.3	0.3	0.2	0.2	0.5
63017	521 Memorial Ave.		0.2	0.6	0.9	0.2	1.4	0.6	0.3	0.3	0.3	0.2	0.2	0.5
63018	St. Ignatius School			0.3	0.5	0.2	1.1	0.5	0.3	0.3	0.1	0.2	0.2	0.4
63019	Main St. Sewage Plant		0.2	0.9	1.3	0.3	2.0	0.9	0.3	0.3	0.7	0.3	0.2	0.7
63020	Hodder Ave. Fire Hall			0.4	0.8	0.2	1.1	0.3	0.1	0.2	0.3	0.2	0.4	0.4
63021	Mission Island			1.2	1.4	0.3	7.2	2.1	0.4	2.5	1.0	0.5	0.4	1.7
63022	14 Algoma St.			1.2	1.1	0.6	1.0	0.6	0.3	0.5	0.5	0.3	0.4	0.6
63024	Hammond Ave./Inter-City			0.9	1.3	0.9	1.7	0.3	0.4	1.0	0.7	0.3	0.4	0.8
63025	Manitou St.			0.6	0.8	0.5	1.3	0.6	0.3	0.3	0.4	0.2	0.2	0.5
63026	North Cumberland Hydro			0.6	0.9	0.3	1.8	0.3	0.3	0.5	0.3	0.2	0.4	0.6
63040	435 James St. South			0.4	0.6	0.2	1.4	0.2	0.3	0.2	0.3	0.2	0.2	0.4

TABLE 3. Insoluble dustfall constituents (volume percent) at four monitoring sites, Thunder Bay, 1976.

Station	Contaminant	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
63005	Grain dust	25	5	5	15	25	10	1	5	2	5	5	<1	8
	Wood char	-	-	-	-	-	-	<1	-	-	-	1	1	<1
	Fly-ash	-	-	-	-	-	-	1	-	2	<1	10	-	1
	Iron oxide	40	-	-	5	10	15	-	-	-	-	-	-	6
	Silica, etc.*	35	95	95	80	65	75	98	95	96	95	84	99	84
63024	Grain dust	80	80	85	85	80	70	<1	65	90	10	75	45	64
	Wood char	20	20	15	15	15	19	<1	-	-	-	5	50	13
	Fly-ash	-	-	-	-	-	-	2	-	-	-	5	-	<1
	Iron oxide	-	-	-	-	-	1	-	-	-	-	-	-	<1
	Silica, etc.	-	-	-	-	5	10	98	35	10	90	10	5	22
63026	Grain dust	90	85	85	90	90	65	5	90	30	30	50	60	64
	Wood char	10	15	15	10	10	34	-	-	10	5	2	40	13
	Fly-ash	-	-	-	-	-	-	5	<1	2	-	-	<1	<1
	Iron oxide	-	-	-	-	-	-	-	-	-	-	-	-	0
	Silica, etc.	-	-	-	-	-	1	90	10	58	65	48	-	23
63040	Grain dust	15	10	10	15	15	-	15	-	5	-	1	5	8
	Wood char	40	55	20	40	40	-	-	-	5	-	-	95	25
	Fly-ash	-	-	5	-	-	5	-	-	-	2	-	-	1
	Iron oxide	-	-	-	10	-	-	-	-	-	-	-	-	<1
	Silica, etc.	45	35	65	35	45	95	85	100	90	98	99	-	66

* Includes non-industrial materials such as plant and insect debris, and soil components.

TABLE 4. Average dustfall (tons/square mile/30 days) in Thunder Bay, 1973-1976.

Station	Location	1973	1974	1975	1976	Four-year average
63003	185 Gore St.	<u>22</u> [*]	<u>21</u>	13	12	17
63004	24 Mountain Road	11	11	10	9	10
63005	McKellar Hospital	<u>15</u>	<u>15</u>	<u>14</u>	10	14
63012	Dawson Court	<u>14</u>	13	10	10	12
63017	521 Memorial Ave.	<u>14</u>	<u>17</u>	<u>15</u>	<u>14</u>	15
63018	St. Ignatius School	10	10	7	9	9
63019	Main St. Sewage Plant	10	<u>20</u>	10	12	13
63020	Hodder Ave. Fire Hall	<u>14</u>	<u>15</u>	<u>16</u>	10	14
63021	Mission Island	<u>15</u>	<u>15</u>	<u>19</u>	<u>16</u>	16
63022	14 Algoma Street	<u>15</u>	<u>16</u>	12	11	14
63024	Hammond Ave./Inter-City	<u>37</u>	<u>29</u>	<u>22</u>	<u>15</u>	26
63025	Manitou Street	<u>19</u>	13	13	11	14
63026	North Cumberland Hydro	<u>25</u>	<u>19</u>	<u>17</u>	<u>16</u>	19
Average, all stations		17	16	14	12	
Stations exceeding criterion (%)		77	69	46	31	

* Values exceeding criterion of 13 (annual average) are underlined.

TABLE 5. Suspended particulate concentrations ($\mu\text{g}/\text{m}^3$), Thunder Bay, 1976.

Date		Station					
		63005	63012	63017	63018	63022	63040
January	1	18	-	18	-	22	-
	7	15	-	-	10	-	-
	13	14	-	15	18	-	21
	19	41	-	44	31	-	-
	25	24	17	22	14	-	-
	31	13	14	19	9	-	10
February	6	15	14	25	16	18	12
	12	55	87	97	42	108	-
	18	49	-	17	14	38	-
	24	51	65	76	52	82	-
March	1	24	14	33	11	42	25
	7	18	13	25	17	21	14
	13	103	20	21	14	25	23
	19	40	97	61	53	52	-
	25	25	-	-	-	-	-
	31	58	-	67	16	25	-
April	6	113	70	195*	51	73	64
	12	119	100	<u>281</u>	111	<u>167</u>	-
	18	27	39	<u>37</u>	24	<u>69</u>	45
	24	88	-	102	55	80	108
	30	-	<u>139</u>	-	85	<u>134</u>	<u>125</u>
May	6	49	34	42	-	-	59
	12	117	<u>159</u>	<u>234</u>	-	<u>175</u>	96
	18	<u>156</u>	<u>77</u>	<u>246</u>	75	<u>121</u>	88
	24	<u>46</u>	37	<u>85</u>	46	<u>58</u>	63
	30	99	<u>146</u>	<u>138</u>	99	120	<u>195</u>
June	5	<u>171</u>	<u>197</u>	<u>251</u>	<u>166</u>	<u>152</u>	<u>260</u>
	11	<u>48</u>	-	<u>100</u>	<u>60</u>	<u>64</u>	<u>65</u>
	17	46	82	90	45	72	76
	23	99	<u>167</u>	<u>197</u>	<u>136</u>	<u>196</u>	<u>145</u>
	29	56	<u>43</u>	<u>107</u>	<u>23</u>	<u>77</u>	<u>68</u>

* Values above criterion of $120 \mu\text{g}/\text{m}^3$ are underlined.

TABLE 5. (continued).

Date		Station					
		63005	63012	63017	63018	63022	63040
July	5	<u>127</u>	90	<u>179</u>	104	<u>176</u>	<u>146</u>
	11	<u>73</u>	32	<u>77</u>	30	<u>51</u>	<u>50</u>
	17	29	-	94	37	46	55
	23	-	-	<u>173</u>	53	67	<u>126</u>
	29	82	<u>156</u>	<u>152</u>	-	<u>140</u>	<u>160</u>
August	4	73	116	<u>173</u>	-	<u>153</u>	-
	10	<u>135</u>	97	-	-	<u>135</u>	<u>172</u>
	16	<u>72</u>	81	<u>180</u>	-	<u>105</u>	<u>88</u>
	22	42	-	<u>115</u>	48	80	80
	28	<u>153</u>	-	<u>388</u>	<u>184</u>	<u>198</u>	-
September	3	86	56	<u>349</u>	72	87	<u>335</u>
	9	47	35	<u>148</u>	56	63	<u>137</u>
	15	95	36	<u>166</u>	55	63	<u>123</u>
	21	23	15	<u>58</u>	19	39	<u>52</u>
	27	-	9	-	21	34	<u>153</u>
October	3	51	-	71	40	61	89
	9	38	36	81	33	65	48
	15	<u>111</u>	97	<u>124</u>	93	<u>144</u>	<u>139</u>
	21	22	-	<u>58</u>	21	<u>38</u>	<u>55</u>
	27	50	35	<u>169</u>	64	91	54
November	2	<u>144</u>	<u>150</u>	<u>194</u>	<u>132</u>	<u>205</u>	-
	8	<u>117</u>	<u>67</u>	<u>114</u>	<u>66</u>	-	13
	14	39	40	99	42	63	16
	20	49	23	94	31	53	<u>276</u>
	26	28	20	-	24	30	<u>56</u>
December	2	28	33	71	26	46	19
	8	23	19	37	19	23	-
	14	24	31	33	20	27	-
	20	28	-	47	15	29	-
	26	20	14	35	13	18	-
Annual geometric means		49	47	<u>82**</u>	37	<u>66</u>	<u>67</u>

** Values above annual criterion ($60 \mu\text{g}/\text{m}^3$) are underlined.

TABLE 6. Concentrations ($\mu\text{g}/\text{m}^3$) of heavy metals, nitrate and sulphate in suspended particulate in 1971 and 1976 at stations 63005 and 63022, Thunder Bay.

Contaminant	63005				63022			
	1971		1976		1971		1976	
	Max	Mean	Max	Mean	Max	Mean	Max	Mean
Cadmium	0.01	<0.01	0.01	<0.01	0.01	<0.01	<0.01	<0.01
Chromium	0.04	<0.01	0.04	<0.01	0.04	<0.01	0.02	<0.01
Copper	0.33	0.12	0.13	0.06	0.45	0.01	0.13	0.04
Iron	8.00	4.10	10.90	2.03	8.80	2.90	8.80	3.00
Lead	1.60	0.70	0.70	0.30	9.30	1.10	1.20	0.46
Manganese	0.25	0.07	0.16	0.06	0.29	0.06	0.21	0.08
Nickel	0.05	0.01	0.05	<0.01	0.06	0.02	0.04	<0.01
Nitrate	3.90	0.90	3.10	0.90	3.30	0.80	4.40	1.10
Sulphate	16.80	7.10	10.10	4.10	11.70	5.20	26.00	5.10
Vanadium	0.05	0.01	0.04	<0.01	0.06	0.01	0.04	<0.01
Zinc	0.50	<0.01	0.10	0.05	0.30	<0.01	0.20	0.06
Average sample size	22		56		24		52	

TABLE 7. Average suspended particulate (annual geometric means, $\mu\text{g}/\text{m}^3$) in Thunder Bay, 1973-1976.

Station	Location	1973	1974	1975	1976	Four-year average
63005	McKellar Hospital	<u>69*</u>	<u>61</u>	51	49	58
63012	Dawson Court	59	51	47	47	51
63017	521 Memorial Avenue	<u>107</u>	<u>102</u>	<u>85</u>	<u>82</u>	94
63018	St. Ignatius School	40	40	36	37	38
63022	14 Algoma Street	<u>74</u>	60	55	<u>66</u>	64
Average, all stations		70	63	55	56	

* Means above criterion of $60 \mu\text{g}/\text{m}^3$ are underlined.

TABLE 8. Two-hour soiling index (COH's/1000 ft), station 63040, Thunder Bay, 1976.

Month	Days of data	Frequency distribution						Maximum values	
		0.0-0.4	0.5-1.0	1.1-1.5	1.6-2.0	2.1-3.0	> 3.0	24-hour	2-hour
Jan									
Feb	9	89	23	1	1	0	0	0.4	1.9
Mar	31	319	43	2	0	1	0	0.5	2.2
Apr	30	349	10	0	0	0	0	0.3	0.9
May	28	327	11	0	0	0	0	0.3	0.7
Jun	30	345	14	0	0	0	0	0.3	0.8
Jul	31	366	6	0	0	0	0	0.2	0.7
Aug	21	247	17	0	0	0	0	0.3	0.9
Sep	28	316	11	2	0	0	0	0.3	1.1
Oct	30	345	13	2	0	0	0	0.3	1.3
Nov	30	346	13	0	0	0	0	0.4	1.0
Dec	28	335	13	0	0	0	0	0.4	1.0
Year	296	3384	174	7	1	1	0	0.5	2.2

TABLE 9. Hourly hydrogen sulphide levels (ppb) at station 63040, Thunder Bay, 1976.

Month	Days of data	Frequency distribution			Maximum 1-hour value
		0	1-20	>20	
January					
February					
March	13	284	39	0	2
April	18	435	18	0	3
May	24	522	52	0	3
June	4	148	0	0	0
July					
August	1	29	1	0	1
September	27	611	59	0	3
October	27	547	117	0	5
November					
December					
Year	114	2576	286	0	5

TABLE 10. Hourly hydrogen sulphide levels (ppb) at station 63046, Thunder Bay, 1976.

Month	Days of data	Frequency distribution			Maximum 1-hour value
		0	1-20	>20	
November	13	244	97	0	16
December	26	387	229	0	15
Year	39	631	326	0	16

TABLE 11. Sulphation rate (mg SO₃/100 cm²/day), Thunder Bay, 1976.

Station	Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
63003	185 Gore St	.10	.14	.17	.12	.07	.08	.04	.05	.13	.08	.05	.12	.10
63004	24 Mountain Rd.	.07	.18	.25	.17	.04	.08	.06	.08	.15	.10	.12	.13	.12
63005	McKellar Hospital	.08	.11	.11	.08	.03	.06	.04	.06	.12	.06	.06	.18	.08
63012	Dawson Court	.07	.10	.13	.28	.05	.10	.06	.06	.12	.05	.08	.13	.10
63017	521 Memorial Ave.	.06	.10	.10	.09	.08	.10	.06	.08	.14	.08	.10	.10	.09
63018	St. Ignatius School	.08	.07	.14	.07	.06	.08	.05	.06	.08	.05	.06	.13	.08
63019	Main St. Sewage Plant	.09	.09	.13	.35	.11	.20	.15	.09	.07	.07	.12	.13	.15
63020	Hodder Ave. Fire Hall	.08	.08	.08	.11	.10	.10	.06	.09	.12	.10	-	.10	.08
63022	14 Algoma St.	.12	.13	.16	.11	.07	.06	.06	.05	.15	.11	.08	.15	.10
63040	435 James St. South	-	.28	.06	.06	<.03	.22	.03	.12	.03	.04	.04	.07	.09

TABLE 12. Average sulphation rates ($\text{mg SO}_3/100 \text{ cm}^2/\text{day}$) in Thunder Bay, 1973-1976.

Station	Location	1973	1974	1975	1976	Four-year average
63003	185 Gore Street	.07	.10	.13	.10	.10
63004	24 Mountain Road	.16	.16	.18	.12	.15
63005	McKellar Hospital	.09	.08	.09	.08	.09
63012	Dawson Court	.11	.09	.08	.10	.10
63017	521 Memorial Avenue	.10	.09	.10	.09	.10
63018	St. Ignatius School	.07	.06	.07	.08	.07
63019	Main Street Sewage Plant	.24	.11	.13	.15	.16
63020	Hodder Avenue Fire Hall	.10	.10	.10	.08	.10
63022	14 Algoma Street	.14	.12	.11	.10	.12
Average, all stations		.12	.10	.11	.10	

TABLE 13. Hourly sulphur dioxide levels (ppm) at station 63012, Thunder Bay, 1976.

Month	Days of data	Frequency distribution					Maximum 1-hour value
		.00-.04	.05-.10	.11-.14	.15-.25	>.25	
January	18	456	0	0	0	0	0.02
February	26	592	0	0	0	0	0.04
March	14	432	0	0	0	0	0.02
April	28	646	6	0	0	0	0.07
May	20	518	5	1	1	0	0.17
June	18	485	0	0	0	0	0.03
July	23	539	1	0	0	0	0.07
August	11	391	0	0	0	0	0.04
September	17	493	1	0	0	0	0.07
October	18	464	0	0	0	0	0.04
November	14	384	0	0	0	0	0.03
December	2	66	0	0	0	0	0.03
Year	209	5466	13	1	1	0	0.17

TABLE 14. Hourly sulphur dioxide levels (ppm) at station 63040, Thunder Bay, 1976.

Month	Days of data	Frequency distribution				Maximum 1-hour value
		.00-.04	.05-.10	.11-.14	>.14	
January	31	682	0	0	0	0.02
February	25	566	0	0	0	0.02
March	31	676	1	0	0	0.05
April	30	659	2	2	0	0.13
May	31	714	0	0	0	0.03
June	30	673	1	0	0	0.05
July	30	671	1	0	0	0.05
August	29	641	0	0	0	0.04
September	25	607	0	0	0	0.03
October	29	689	2	0	0	0.05
November	29	647	0	0	0	0.03
December	25	560	0	0	0	0.01
Year	345	7785	7	2	0	0.13

TABLE 15. Hourly sulphur dioxide levels (ppm) recorded in 1976 by Ontario Hydro at five Thunder Bay monitoring sites.

Month	Frequency distribution					
	.000-.049	.050-.099	.100-.149	.150-.199	.200-.249	>.249
Station 63023						
January	738	0	0	0	0	0
February	623	0	0	0	0	0
March	740	3	0	0	0	0
April	712	4	2	0	0	0
May	737	5	0	0	0	0
June	707	3	0	0	0	0
July	738	0	0	1	0	0
August	696	15	0	0	0	0
September	717	0	0	0	0	0
October	744	0	0	0	0	0
November	707	0	0	0	0	0
December	732	1	0	0	0	0
Year	8591	31	2	1	0	0
Station 63041						
January	740	0	0	0	0	0
February	675	2	0	0	0	0
March	742	0	0	0	0	0
April	718	0	0	0	0	0
May	271	0	0	0	0	0
June			no data			
July	33	3	0	0	0	0
August	737	0	0	0	0	0
September	717	1	0	0	0	0
October	733	5	0	0	0	2
November	716	0	2	0	0	0
December	332	0	0	0	0	0
Year	6414	11	2	0	0	2

TABLE 15. (continued).

Month	Frequency distribution					
	.000-.049	.050-.099	.100-.149	.150-.199	.200-.249	>.249
Station 63042						
January	744	0	0	0	0	0
February	672	12	1	0	0	0
March	699	7	1	0	0	0
April	522	1	0	0	0	0
May	687	0	0	0	0	0
June	712	1	0	0	0	0
July	741	0	0	0	0	0
August	740	0	0	0	0	0
September	342	0	0	0	0	0
October	621	0	0	0	0	0
November	718	0	0	0	0	0
December	736	0	0	0	0	0
Year	7934	21	2	0	0	0
Station 63043						
January	744	0	0	0	0	0
February	694	0	0	0	0	0
March	727	0	0	0	0	0
April	713	0	0	0	0	0
May	737	0	0	0	0	0
June	719	0	0	0	0	0
July	744	0	0	0	0	0
August	742	0	0	0	0	0
September	702	0	0	0	0	0
October	711	0	0	0	0	0
November	718	0	0	0	0	0
December	738	0	0	0	0	0
Year	8689	0	0	0	0	0
Station 63044						
January	730	0	0	0	0	0
February	621	19	4	2	1	1
March	733	9	0	0	1	1
April	649	33	13	4	5	13
May	466	0	0	0	0	0
June	642	0	1	0	0	0
July	362	2	0	0	0	0
August	732	4	2	0	0	0
September	675	3	0	1	0	0
October	741	0	0	0	0	0
November	718	0	0	0	0	0
December	738	4	0	0	0	0
Year	7807	74	20	8	7	15

TABLE 16. Analysis of high sulphur dioxide concentrations at stations 63041 and 63044, Thunder Bay, 1976.

Station	Date	Hour	Average hourly concentration (ppm)	Wind direction*
63041 (Mt. McKay)	October 27	0400	0.26	SW
		0500	0.41	W
63044 (James St. & Hwy. 61B)	February 24	1000	0.27	W
	March 22	0800	0.58	W
	April 2	0400	0.28	WSW
		0600	0.87	SW
		0800	0.35	SW
	" 4	0300	0.54	SW
		0600	0.33	SW
	" 7	0100	0.28	W
	" 8	0400	0.47	SW
	" 10	0300	0.28	WNW
	" 13	0300	0.30	WSW
		0400	0.40	SW
		0500	0.87	WSW
		0600	0.36	SW
		0900	0.27	C

* From hourly measurements made 10 m above ground level at Thunder Bay airport.

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